ADA

IMPACT OF FIRE RESISTANT FUEL BLENDS ON FORMATION OF OBSCURING FOG

TFLRF INTERIM REPORT
TFLRF No. 403

by

Bernard R. Wright

Edwin A. Frame

U.S. Army TARDEC Fuels and Lubricants Research Facility

Southwest Research Institute® (SwRI®)

San Antonio, TX

for

U.S. Army TARDEC

Force Projection Technologies

Warren, Michigan

Contract No. DAAE-07-99-C-L053 (WD38)

August 2010

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14. ABSTRACT
The lack of adequate smoke with JP-8 in the Vehicle Engine Exhaust Smoke System (VEESS) is detrimental to the effective use of JP-8 as the single battlefield fuel. The VEESS is considered a force multiplier and is very critical in armor strategies. Efforts of this study centered on quantifying the obscuration of smoke produced by FRF blends. All fuel blends were examined in a diesel VEESS screener that was developed to emulate actual VEESS parameters. Results indicated that FRF blends did not produce more smoke than the base fuels.

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VEESS, JP-8, FRF

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EXECUTIVE SUMMARY

During an Army research program in the Mid-1980's, Southwest Research Institute (SwRI) developed a fire-resistant diesel fuel that would self extinguish when ignited by an explosive projectile. This fire resistant fuel (FRF) was composed of a stable mixture of diesel fuel, 10% water, and an emulsifier. The research program ended in 1987 without the FRF blend being fielded due to several reasons, including some technical problems. Recently, due to the war in Iraq and Afghanistan, there has been a renewed interest in FRF development. The Army research program was restarted to continue development of FRF, with a redefined scope to include the development of FRF using JP8 to comply with the Army's Single Fuel Forward strategy.

During the 1990's, the U.S. Army and the U.S. Air Force changed over to a common fuel (JP-8), known as the "One Fuel Forward", JP-8 is Jet-A with several additives to enhance performance. JP-8, when tested as a FOG producing agent, did not produce adequate smoke (FOG). FOG production is closely related to volatility (flashpoint) and JP-8 with a low flashpoint did not produce adequate smoke. With the development of fire resistant fuel (FRF), it was decided to test this new fuel blend for smoke (FOG) production. FRF blends (84% base fuel, 6% surfactant and 10% water (blend 1) and same FRF fuel blend + anti-mist agents (high molecular weight polymers) were tested in the restored laboratory smoke generating apparatus. Results from earlier testing were recorded, i.e. JP-8 FRF produced minimal smoke while diesel FRF produced large quantities of obscuring smoke, thus correlating with data obtained in earlier studies. There was minimal, if any contribution from the additives blended into the fuels.

FOREWORD/ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

ACRONYMS AND ABBREVIATIONS

AMA	anti-mist agent
CM	centimeter
FRF	fire resistant fuel
HC	hydrocarbon
mL	milliliter
NOx	oxides of nitrogen
ppm	parts per million
RPM	revolutions per minute
SwRI®	Southwest Research Institute
TARDEC	Tank Automotive Research and Development Command
TFLRF	U.S. Army TARDEC Fuels and Lubricants Research Facility
VEESS	Vehicle Engine Exhaust Smoke System

1.0 INTRODUCTION

Since the concept of smoke generation was developed prior to World War 1, smoke has been used as an obscurant in both defensive and offensive operations. Smoke is employed in offensive operations primarily to neutralize enemy firepower and reduce mobility; for defensive operations, smoke is used to neutralize enemy observation and aimed enemy fire. Employment of obscuring smoke on an attacking armored force may cause it to reduce speed, change its direction, deploy prematurely, and/or rely on non-visual means of command and control. Smoke employment in offensive operations is primarily for neutralizing enemy firepower and reducing mobility.

2.0 APPROACH

Decisions within the Department of Defense in the late 1980's, that all land-based air and ground equipment will be operated on F-34 (JP-8) instead of F-54 (DF-2) have caused a severe problem to surface. The U.S. Navy continued to use JP-5 fuel for carrier-based aircraft. This problem is related to the smoke (fog)-producing requirement as it currently is prescribed under both offensive and defensive battlefield scenarios. Essentially all armored ground equipment is equipped with a vehicle engine exhaust smoke system (VEESS) that is used to produce smoke by injection of fuel from the main fuel system into a section of the heated exhaust. Basically, the principle of operation of the VEESS is evaporation of the liquid fuel, and then condensation of the fuel vapor outside of the exhaust system into a visible light-obscuring fog. Requirements of an effective fog in this program are that it obscures in the visible light range and persists for some period of time without evaporating or settling out due to condensation into large droplets. Several factors affect the ability of JP-8 to produce a satisfactory smoke, perhaps the most important are vapor pressure and volatility.

2.1 Bench-Scale Smoke Producing Apparatus

A fog-generating device for bench-scale evaluation of candidate samples was designed and built in the earlier program (Reference 1 & 2). The following requirements for this experimental test device were the basis of the design:

a) A fog-generating device that provides repeatable temperature profiles;
b) An accurate method to introduce the fog-oil candidate into the heated reaction chamber;
c) A method to maintain a constant dilution ratio of the smoke being generated;
d) A method to accurately assess the obscuration provided by the generated smoke and to provide a comparison between the various samples being tested.

The bench-test apparatus consisted of a gasoline-powered 208 cu cm Stens engine fitted with an exhaust assembly. This assembly consisted of a 1-inch (2.5 cm) diameter by 11.75-inch (29.8 cm) length conduit tubing that served as the reaction chamber. This reaction chamber discharged into a 14-inch (35.6 cm) diameter by 10-foot (3.05 cm) length of piping. The engine was operated at approximately 960 rpm, and the temperature of the exhaust gases was measured at four thermocouple positions.

A generator placed a load on the engine for temperature and speed control. A positive displacement pump was used to feed the sample at a constant flow of 6 mL per minute into the hot engine exhaust for vaporization. The temperature of the engine exhaust during sample vaporization was maintained at approximately 900°F. An exhaust fan assists the smoke (fog) that is generated to flow past a photo cell at a relatively constant rate. A profile map of the air velocity at the end of the reaction chamber (near the photo cell) was made in order to duplicate the test conditions at another location if moved. The obscurancy is measured with the photo cell attached to a strip recorder. The experimental set up is shown in Figure 1.

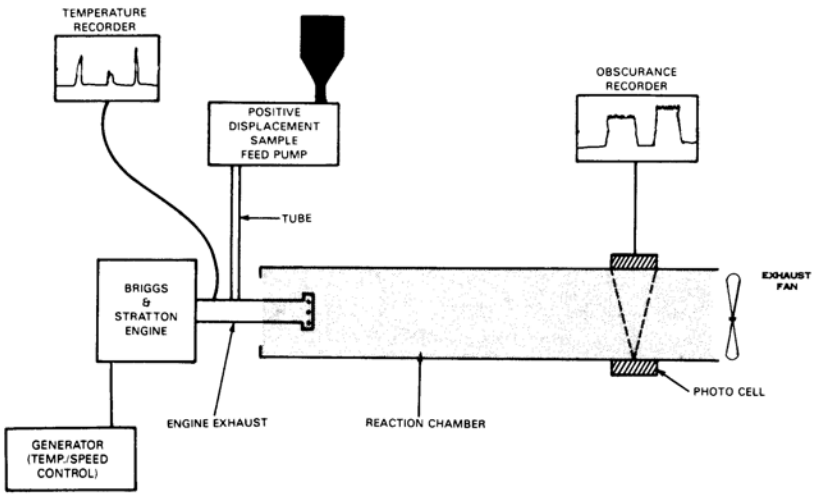

Figure 1. Simplified Schematic of Fog Generating Device

2.2 Reactor Temperature Profile

The procedure, as it was used, consisted of the introduction of the test fluid in a controlled, repeatable manner by a constant volume displacement pump. Flow rates were varied initially to determine the optimum flow rate for the heat generated with the single-cylinder exhaust gas generator. If the fluid were pumped into the exhaust system faster than it could be vaporized, the fluid simply flowed out the end of the reactor, thus providing a false reading. Figure 2 shows a typical response to the introduction of the fluid. The reactor was heated to approximately 1050°F (566°C) and, with the onset of injection, stabilized at approximately 900°F (482°C) for the duration of the injection cycle. The result of the injection of the fluid is then monitored on the photocell downstream from the engine.

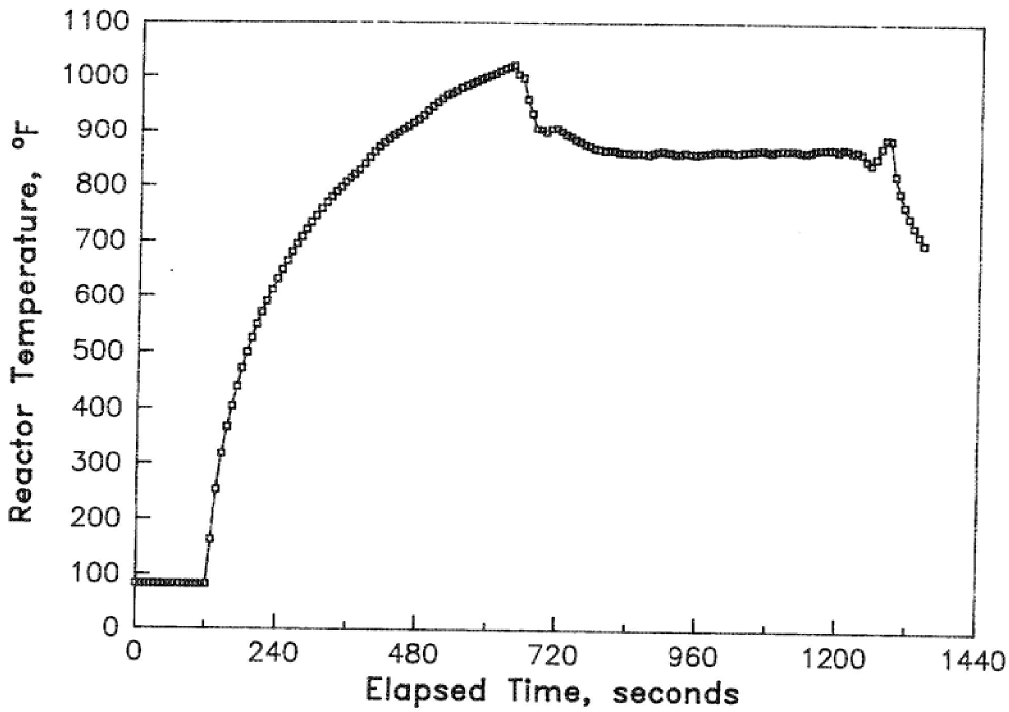

Figure 2. Typical Temperature Profile of Reactor during Fluid Injection

2.3 Photocell Response

Figure 3 shows a typical photocell response to the ongoing evaporation-condensation process. The important parameters of this process is for the reactor temperature remain constant (and in a range simulating the VEESS temperatures) and that the fluid flow rate remain constant. With these controlled parameters, the data obtained will be directly compared to the reference fluid (Fog Oil in this case) on an equal volume basis. It was thought that increased smoke levels could be achieved simply by increasing the fluid flow rate, using care not to exceed the amount of generated heat available within the system for evaporation purposes. As stated earlier, excess fluid will simply drip from the end of the reactor tube.

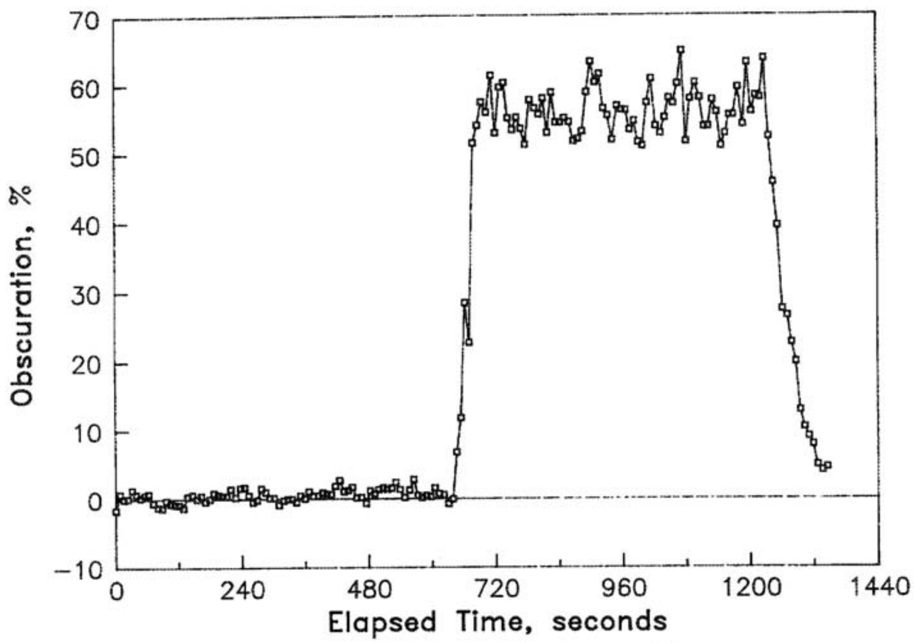

Figure 3. Typical Photocell Response to Smoke Formed in Reactor

3.0 RESULTS AND DISCUSSION

The results of the three base fuels used in the laboratory testing are shown in Table 1. The minimum flashpoint of JP-8 and Jet-A is 100°F, however, a wide variety of flashpoint fuels are used in the field. Examples of this are shown in Table 1, 2a and 3a. These differences have been also documented in various flammability testing results. The results obtained from fog oil, a standard fluid commonly used in the field, were used as a 100% obscuration reference point in this study. Therefore, the test fuel samples were compared on that basis. Samples 2b, 3b, and 4b were standard FRF blends containing 84% fuel, 6% schercomid surfactant and 10% water. The results of this study indicates, that the addition of these blending components had no affect on the obscuration characteristic compared to the base fuel. Also the addition of 125 ppm anti-mist agent polymers to the standard FRF formulation had very little effect, in fact, appeared to reduce the obscuration performance of the FRF blend.

Table 1. Fog Oil Obscuration Testing Results

Sample	Flashpoint	Obscuration Rating
1. Fog Oil		100%
2a. AF-6958 – JP-8 2b. AF-6958 – JP-8-FRF 2c. AF-6958 – JP-8-FRF+AMA	41°C	a). 4.4 b). 6.8 c). 2.8
3a. AF-7090 – JetA 3b. AF-7090 – JetA-FRF 3c. AF-7090 – JetA-FRF+AMA	56°C	a). 5.3 b). 4.8 c). 3.8
4a. AF-6795 – Diesel 4b. AF-6795 – Diesel-FRF 4c. AF-6795 – Diesel-FRF+AMA	66°C	a). 88 b). 79 c). 62

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